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REPLY TO ATTN OF: GP

(NASA-Case-LEW-10920-1) METHOD AND APPARATUS FOR SPUTTERING UTILIZING AN APERTURED ELECTRODE AND A PULSED SUBSTRATE BIAS Patent (NASA) 3 p CSCL 11F

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TO: KSI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code KSI, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No. : 3,732,158

Government or Corporate Employee : U.S. Government

Supplementary Corporate Source (if applicable) : ________

NASA Patent Case No. : LEW-10920-1

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:
Yes [ ] No [ ]
Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of column No. 1 of the Specification, following the words ". . . with respect to an invention of . . ."

Elizabeth A. Carter

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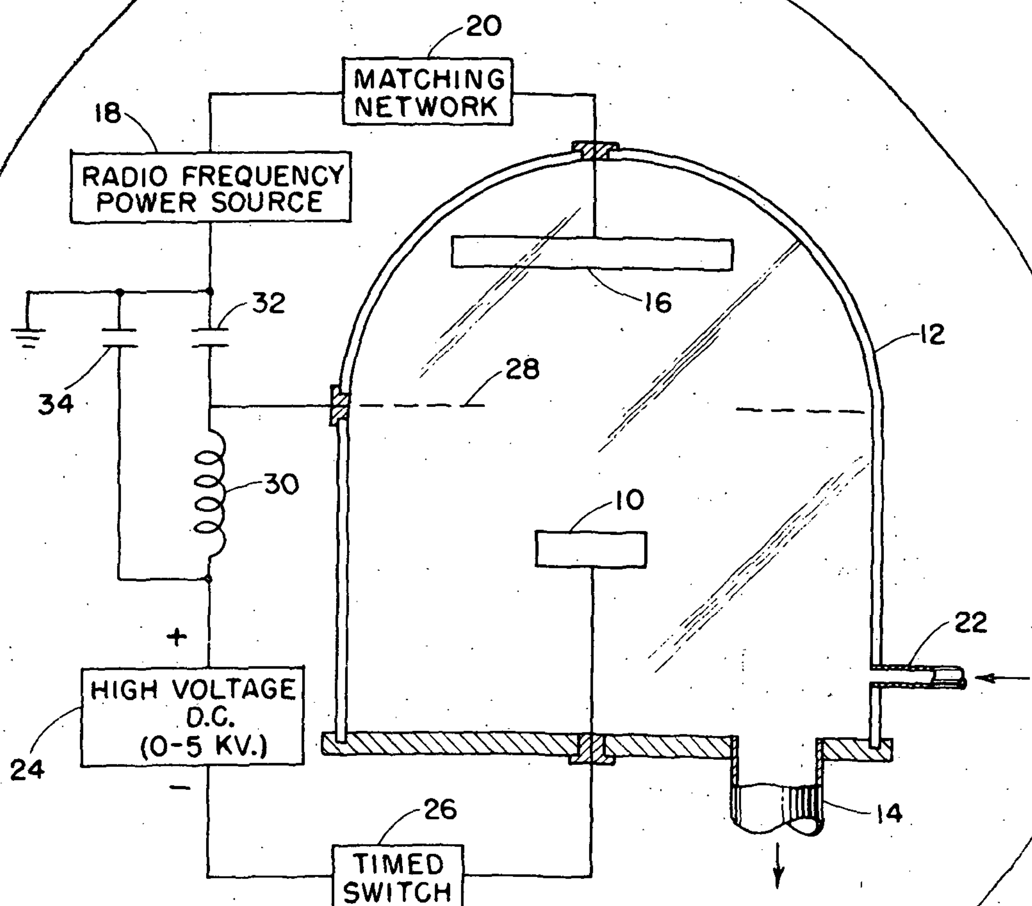
Enclosure
Copy of Patent cited above

May 8, 1973 J. S. PRZYBYSZEWSKI ET AL 3,732,158

METHOD AND APPARATUS FOR SPUTTERING UTILIZING AN APERTURED ELECTRODE AND A PULSED SUBSTRATE BIAS

Filed Jan. 14, 1971



US-PATENT- 3,732,158 40%

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METHOD AND APPARATUS FOR SPUTTERING UTILIZING AN APERTURED ELECTRODE AND A PULSED SUBSTRATE BIAS

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U.S. Cl. 204—192 7 Claims

ABSTRACT OF THE DISCLOSURE

Combining the advantages of ion plating with the versatility of a radio frequency sputtered source. A pulsed high voltage direct current is passed to the article being plated during radio frequency sputtering.

ORIGIN OF THE INVENTION

The invention described herein was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

This invention is concerned with plating adherent films on objects having complex geometries. The invention is particularly directed to ion plating alloy films on such objects using a radio frequency sputtered source. The ion plating process is modified because this source supplies film material at a much slower rate than the usual thermal evaporation source.

In the past several methods were used to deposit various types of films on simple as well as geometrically complex objects. While each process is satisfactory for certain applications, problems have been encountered with all of these methods.

Conventional vapor deposition is conducted in a vacuum of 10^{-6} to 10^{-8} torr. The use of conventional vapor deposition has been generally restricted to the elemental metals, although some metal alloy systems as well as certain semiconductors and nonconductors have been vapor deposited. The high vacuum used in vapor deposition reduces the concentration of gas molecules which increases the mean free path. Very little scattering of the film material results, and the process is limited to line-of-sight deposition. The coating of complex geometries by vapor deposition is conditioned on the rotation of the object to be coated. Adherence of a vapor deposited film is poor because of the low energy of the impinging film material.

The film adhesion is improved when either direct current or radio frequency sputtering is used. Direct current sputtering has been successful for depositing elemental metals, semiconductors, and metal alloy systems. This type of sputtering is not useful for depositing nonconductors. Radio frequency sputtering has been used for depositing elemental metals, metal alloy systems, semiconductors, and nonconductors. This type of sputtering is not limited by the nature of the film material. It can be used to sputter almost any material from insulators through semiconductors to metals.

Radio frequency and direct current sputtering are generally done in an atmosphere having a pressure in the range of about 5 to 20 microns. Because of this relatively high pressure the sputtered material is scattered. The mean free path is short, and the material is diffused rapidly as it leaves the source. Even though this scattering effect causes film formation on surfaces not directly facing the source material, both RF and DC sputtering are considered to be line-of-sight deposition processes. The low energy of the impinging film material adversely affects film adherence.

Ion plating is performed at about the same pressure as RF and DC sputtering. A high voltage is applied to the object to be coated. This results in a uniform coating on all sides without rotating or moving either the object or the source of film material. While the coating has excellent adhesion, problems have been encountered because the process utilizes a thermal evaporation source. This limits the film materials to the elemental metals and those compounds which do not dissociate before they evaporate.

SUMMARY OF THE INVENTION

These problems have been solved by the present invention which utilizes radio frequency sputtering with a pulsed high voltage direct current. The process is not limited to a line-of-sight deposition, and complex geometries can be plated without rotation. The process is useful for plating adherent films of elemental metals, metal alloy systems, semiconductors, and nonconductors.

OBJECTS OF THE INVENTION

It is, therefore, an object of the present invention to plate an adherent alloy film on an object having a geometrically complex configuration.

Another object of the invention is to provide an improved plating method which combines the advantages of ion plating with the versatility of a radio frequency sputtered source.

A further object of the invention is to provide an improved method for plating alloy films on complex geometries without rotation during the plating process.

These and other objects of the invention will be apparent from the specification which follows and from the drawing wherein like numerals are used throughout to identify like parts.

DESCRIPTION OF THE DRAWING

The figure is a schematic diagram of a system constructed in accordance with the invention for plating adherent alloyed films on geometrically complex objects.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing there is shown an object **10** which is to be coated in accordance with the present invention. The object **10** may be any electrically conductive article having either a simple or geometrically complex configuration. By way of example the invention has been utilized to coat bearings with a solid lubricant. The object **10** is mounted in a chamber **12** that is connected at **14** to a suitable vacuum pumping system.

A target **16** of the material to be sputtered is likewise located in the chamber **12**. The target **16** is connected to a radio frequency power source **18** through a matching network **20**. This RF sputtered source **16** is utilized instead of a thermal evaporation source normally used in ion plating. As stated earlier, certain modifications are required because the RF sputtered source **16** supplies film material at a much slower rate than a thermal evaporation source.

A suitable gas is supplied to the chamber **12** at an inlet **22**. Argon is preferably used. The object **10** to be plated is connected to a high voltage, direct current source **24**. The source **24** preferably has a range of 0 to 5 kilovolts.

In this manner the ion plating is carried out in a low pressure ionized gaseous atmosphere with the object **10** to be plated forming a cathode that is maintained at a high negative potential from the source **24**. Consequently, the object **10** to be plated is continuously bombarded or sputtered by ions before, during and after film material

enters the ionized gas. If the evaporation rate of the film material is too slow the film on the object to be plated will be sputtered away as fast as it develops, and no film will result. Because the RF sputtered source **16** is inherently slow, no film would develop under normal ion plating conditions.

According to the present invention the ion plating process has been modified to reduce the rate of sputtering off of the newly formed film by providing a timed switch **26** between the source **24** and the object **10**. The reduction in the sputtering off rate is accomplished by pulsing the negative high voltage DC from the source **24** to the object **10** by means of the timed switch **26**.

A third electrode **28** is positioned in the chamber **12** to establish a common electrode between the RF power source **18** and the DC power source **24**. The electrode **28** is connected to the high voltage DC power source **24** through an RF choke **30**. The electrode **28** forms an anode with respect to the cathode **10**. The radio frequency power source **18** is connected to the electrode **28** through a capacitor **32**. A bypass capacitor **34** is likewise provided.

This third electrode **28** is preferably in the form of a perforated plate or screen that is located between the sputtered source **16** and the object **10**. The screen has an aperture in the center to enable sputtered material to pass to the object to be plated.

In operation, the object **10** is mounted in the chamber **12** together with the target **16** of material to be sputtered. The chamber **12** is partially evacuated and a gaseous atmosphere from about 10–20 microns pressure is established. A high voltage DC negative potential of 2 to 5 kilovolts with respect to the screen **28** is continuously applied to the object **10**. This establishes a glow discharge within the vacuum chamber **12** to sputter clean the object **10**.

After a predetermined period of sputter cleaning, the high voltage DC source **24** is deenergized and the gaseous pressure is lowered to about 10 microns. The RF power source **18** to the film material **16** is energized, and sputtering of the film material begins. At this point the high voltage DC source **24** is switched to a timed on-off mode by the switch **26**. In this manner the high voltage DC is reenergized and reapplied to the object **10**.

The pulsed high voltage direct current RF sputtering process produces an intense electric field which completely surrounds the object **10**. This can be seen as a dark space around this object. Any ionized material entering this region gains kinetic energy from the field and impacts on the surface of the object **10** with great force. This contributes to improved adhesion. The dark space, in effect, represents essentially a source of film material which takes on the general outline of the object **10**.

The high voltage DC negative potential on the object **10** is maintained throughout the plating. The process is continued until the desired film is obtained. The reduced sputtering rate of the film on the object **10** results in the formation of a visible film having excellent adherence and covering the entire object.

EXAMPLE

Pulsed high voltage direct current radio frequency sputtering was used to plate antifriction bearing components with a solid lubricant film of molybdenum disulfide. The plating conditions are as follows:

Total coating time each component: 3 hours
Radio Frequency Input Power to Source Material: 700 watts at 7 megahertz
Maximum pulse amplitude to specimen: 2000 V-DC, negative
Pulse form: 15 seconds on; 5 minutes off; 5% duty cycle
Specimen to screen distance: 2.5 inches

Specimen to source distance: approximately 6 inches
Chamber pressure: 5 microns; argon

The components were assembled and the bearing was tested. The bearing was satisfactory for its intended use.

While one embodiment of the invention has been shown and described it will be apperciated that various modifications to the invention may be made without departing from the spirit of the invention or the scope of the subjoined claims.

What is claimed is:

1. In a sputtering apparatus, including a vacuum chamber, means for admitting a gas into said chamber, target holding means for supporting the material to be sputtered, substrate holding means for supporting a substrate to be coated, means for applying RF potential to said target to sputter said material, and means for applying a high voltage direct current to said substrate;

the improvement wherein an apertured electrode is disposed between said substrate holding means and said target holding means, said electrode being connected to said means for applying RF potential and said means for applying a high voltage direct current whereby a high voltage direct current negative potential with respect to said electrode is applied to said substrate holding means and an RF potential is applied to said target holding means to sputter said material, and

timed switch means connected to said means for applying a high voltage direct current, said timed switch means enabling said high voltage direct current negative potential to be pulsed from of about 15 seconds on and about 5 minutes off.

2. Apparatus as claimed in claim **1** wherein said apertured electrode is a screen.

3. Apparatus as claimed in claim **2** wherein the screen has a centrally disposed aperture therein.

4. In an RF sputtering process wherein an RF potential is applied to a target to sputter material from the target onto a substrate, the improvement comprising disposing an apertured electrode between the target and the substrate, connecting said electrode to a source of RF potential and to a source of high voltage direct current, and applying to said substrate a high voltage direct current negative potential pulse from of about 15 seconds on and about 5 minutes off.

5. A method as claimed in claim **4** wherein said pulsed voltage is a potential of about 2 to 5 kilovolts.

6. A method as claimed in claim **4** including disposing said target about 2.5 inches from said apertured electrode and said substrate about 6 inches from said apertured electrode.

7. A method as claimed in claim **6** wherein argon is utilized at a pressure of about 10 microns.

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